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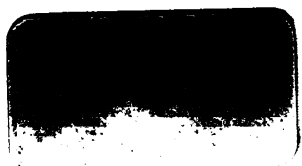
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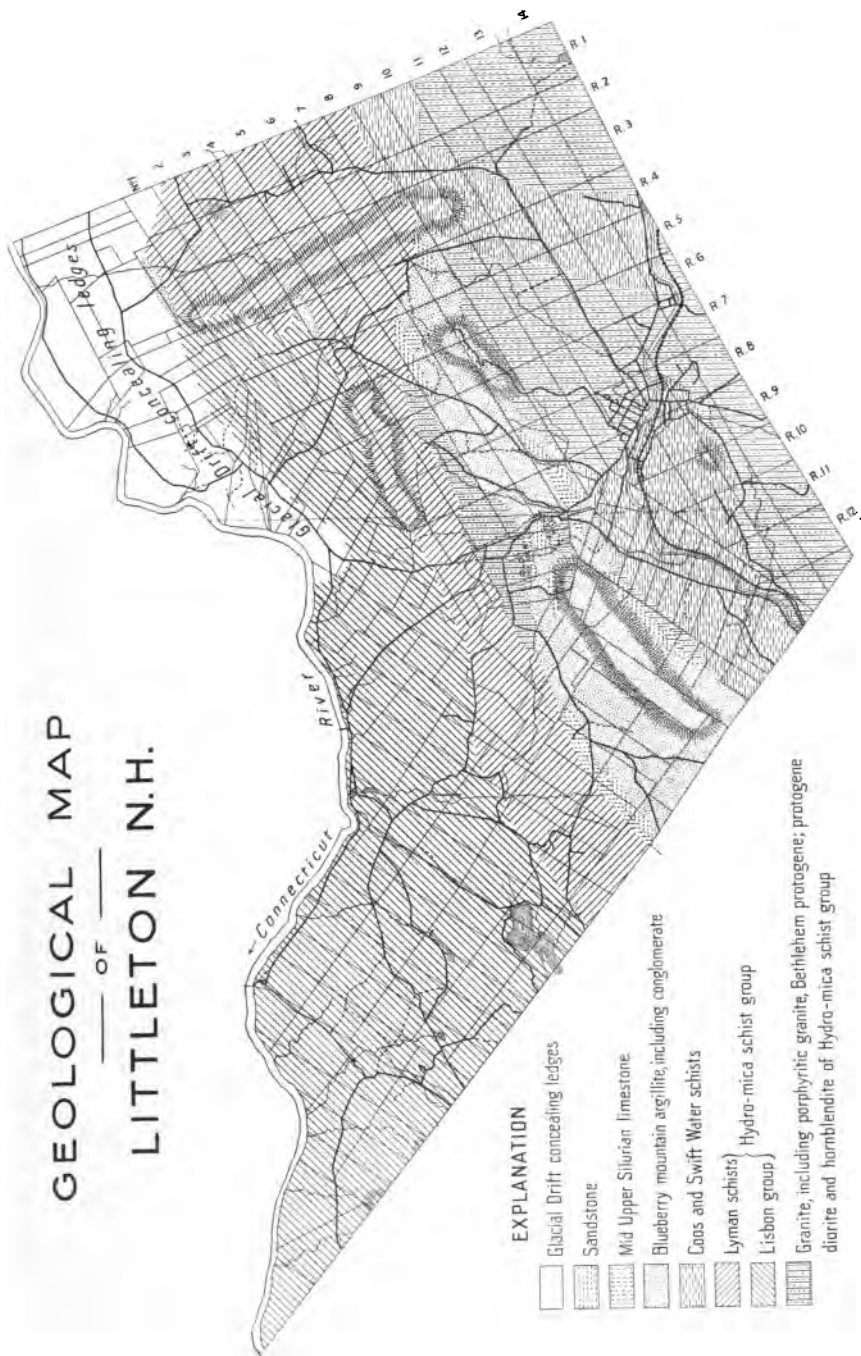
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GEOLOGICAL MAP OF LITTLETON N.H.



THE GEOLOGY
OF
LITTLETON
NEW HAMPSHIRE

G-H

BY
C. H. HITCHCOCK, PH.D., LL.D.

WITH AN ARTICLE ON A TRILOBITE FROM LITTLETON,
AND NOTES ON OTHER FOSSILS FROM
THE SAME LOCALITY

BY
AVERY E. LAMBERT

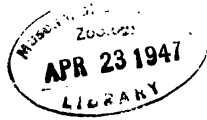
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THE GEOLOGY OF LITTLETON.

By C. H. HITCHCOCK, PH.D., LL.D.

SUNDRY facts relating to the geology of Littleton have appeared in C. T. Jackson's State Report, 1844; in the Geology of the State of Vermont, 1861; in the Annual and Final Reports of the State Survey, 1868-1878; a Paper upon the Helderberg of New Hampshire, etc., in the American Journal of Science, 1874; an Atlas of the State of New Hampshire, by Comstock and Kline, 1877; Geological Sections across New Hampshire and Vermont, in the State Agricultural Report for 1884; and lastly, a notice of the Discovery of Trilobites, by T. Nelson Dale, in a Canadian publication.

The present sketch is based upon the facts contained in these publications, supplemented by several visits made subsequently for the purpose of gaining more precise information. New facts have been discovered at each visit, and the rapid progress of the science necessitates a rearrangement of the conclusions not anticipated. It is to be regretted that our knowledge is still so incomplete.

The township is traversed by two rivers, — the Connecticut and the Ammonoosuc. The first constitutes the boundary on the north-west side, more than thirteen miles long. The principal portion of the "Fifteen Miles Falls" is situated within the limits of Littleton. The head is in Dalton, to the north, 830 feet above the sea, and the foot in Monroe, near the mouth of the Passumpsic, 460 feet above the sea, the total fall being 370 feet. Of this amount, 300 feet lie within the town limits. With such a great descent, the river is narrow and the shores rocky, with an absence of the intervals so abundant in both the upper and lower sections of the river. These features result from the geological conformation. A range of mountains has been cut across by the river. It is the Gardner Mountain range, 2000 feet high, coming northerly through Bath, Lyman, and Monroe, and falling rapidly to the water level in West Littleton, to rise again in Waterford, Vt. The second

valley lies parallel to the first, and may owe its inception to the presence of softer rocks, which have been excavated along their trend, while in the first instance the cutting has been effected directly across the strata. These facts may suggest at some period the drainage of the northern Connecticut through the Ammonoosuc valley.¹

Between these two valleys the land is mountainous the whole length of the township. A gap near the village separates the mass into two sections. That to the south is the Blueberry Mountain; that to the north occupies the width nearly of the whole township, and the names upon the old county map are for the western line, — Wheeler Hill, Palmer Hill, Morse Hill, and Mount Misery. This map gives only Mann's Hill upon the eastern side, to which should be added Palmer Hill. Mr. Gile's map combines Mann's Hill and Morse Hill into Black Mountains, with a course somewhat north of west, and attaining the altitude of 2000 feet above tide water. The other mountains named reach, in many cases, the altitude of 1900 feet. The mountains in the northern section constituted a broad plateau originally, from which the drainage now flows in every direction.

Upon the older geological maps the rocks were represented as granitic and Archean. Fortunately, well-defined fossils have since been discovered, which convey exact information of the age of the associated strata. The history of the discovery is interesting. The writer had been examining the limestones near the sites of the old kilns on Parker Brook and Burnham Hill, and detected the presence of crinoidal stems and coralline bunches. Aware of the importance of the discovery, he at once telegraphed this message to the Dartmouth Scientific Association, Hanover: "No longer call New Hampshire Azoic. Silurian Fossils discovered to-day, Sept. 28, 1870." The fossils found in 1870 were submitted to E. Billings, Paleontologist of the Canada Geological Survey. He found among them *Favosites basaltica*, *Zaphrentis*, and crinoidal fragments, but nothing enabling him to localize the horizon more definitely than by the general term of *Helderberg*, Devonian-Silurian. The Devonian part of the Helderberg was known to Mr. Billings at Memphremagog Lake, fifty-five miles distant; and that knowledge evidently biassed his opinion at that time.

The next important discovery came three years later. In answer to inquiries about the existence of limestone, Mr. A. R. Burton had told us of the existence of that rock upon the farm of Mr. E. Fitch; and a party of us, including J. H. Huntington and A. S.

¹ See Geology of Vermont, Vol. I. p. 116.

Batchellor, set out for its exploration, September 22, 1873. Mr. Huntington had the honor of first recognizing the outlines of a shell, and soon we all had more specimens of well-defined brachiopods and corals than we could carry away.

These additional fossils did not cause Mr. Billings to be more precise in the recognition of the horizon. Later, we found large masses of *Halysites*, or chain coral. On submitting these, with the others, to Prof. R. P. Whitfield, of New York, it was perceived that the horizon was distinctly that of the Niagara limestone, as determined by the presence of the chain coral and the brachiopod, which proved to be the *Pentamerus Nysius*, and both species are specifically characteristic of the Niagara. Later, Mr. T. Nelson Dale visited the locality, and discovered the trilobite known as the *Dalmania limulurus*, also a Niagara species. Hence the existence of a Niagara horizon is well established. As will appear later, other horizons may be represented as well; and that there is still opportunity for the discovery of Helderberg species. In my State Reports I have used the name "Helderberg," but in later publications have changed to "Niagara," because there is certainty in respect to the existence of the earlier terrane on Fitch Hill. The term "Helderberg" may be useful when speaking of the related rocks.

The rocks of Littleton may be classed as, *first*, granitic; *second*, schistose; *third*, the fossiliferous Niagara and associated slates and sandstones. It will be convenient to describe them in this order, without reference to their exact succession.

The granitic rocks occupy three areas, and have been described in the State Report as the *Porphyritic gneiss* or *granite*, *Protogene* or *Bethlehem gneiss* or *granite*, and *ordinary gneiss*, believed to be the *Atlantic* or *Winnipiseogee series*. Such were the terms used in 1877. Since then the study of crystalline rocks has made great progress, and it will be best to modify the earlier opinions with reference to structure and origin.

It was necessary for the New Hampshire Geological Survey to enter upon the study of crystalline rocks, making use of the new methods in the employment of the compound microscope and polarized light. The services of the late Dr. G. W. Hawes were called into requisition, and the report he prepared for the State upon Lithology and Mineralogy opened the way for the study of related crystalline rocks by others. The conclusions of Dr. Hawes have been fortified and supplemented by the later workers.

The peculiarity of such of these rocks as occur in Littleton is that they are traversed by lines of mineral arrangement called

foliation, and the material may be cleaved readily by the application of blows with steel utensils, hammers, or chisels. Such rocks are termed *schists*, because of their easy splitting, and the arrangement can be called a crystalline lamination. Most schists possess banding that is unmistakable. These granitic masses in Littleton are imperfectly foliated, — so much so that different geologists will call them granite or gneiss, according to their predilections. Now granite has tendencies to cleave where the foliation cannot be perceived to exist by the eye, but may be present, so that some hesitation in deciding upon the presence or absence of foliation is pardonable. My present belief is that all these rocks are true granites rather than schists.

When this tendency to split was observed by the geologist of twenty-five years ago, he had before him the conclusions of his instructors that schists occupied the place of strata. Alternating bands of strata would have varying composition. The action of thermal influences with water would cause the molecules to rearrange themselves according to their affinities, and thus to form crystals, which would be as different in respect to coloration as were the original strata. The earlier geologists saw no way in which these crystalline laminæ could have been formed except through the metamorphism of sediments, and hence foliation was said to be identical with stratification, only that sometimes one set of planes might cut across others. On studying the phenomena of cleavage, it became apparent that lines of structure perfectly comparable with strata could be superinduced. It is the result of pressure. Suppose this admitted fact be applied a little further. Let us take a mass of granite just formed, still somewhat plastic. The constituent minerals lie in every conceivable position, perhaps well expressed by the statement that no two of the flat minerals lie in the same plane. Now let pressure be applied to this plastic bunch. All the flat minerals will be made to lie at right angles to the force exerted, and consequently parallel to one another. When an attempt is made to break the rock, splitting will follow the lines of arrangement of the flat minerals. If the pressure has been free to act for a long time, genuine foliation will be the result. Hence it is possible to understand the origin of schists possessing no trace of sedimentary origin. It will be easier to believe the granitic rocks of Littleton originated in this way than from the alteration of sediments. If the foliation is distinct, however, the rock is a gneiss rather than granite.

In entering upon the descriptions of these granitic areas it is assumed that they are all of igneous origin, and that their folia-

tion has been induced by pressure; that they are not altered sediments, although metamorphism has acted vigorously upon clastic rocks in other parts of the town, — in fact in districts adjacent to these granites, because the source of the heat is thus understandable. Pains have been taken to record the positions occupied by the foliation, partly because of the habit acquired when these were supposed to represent sedimentation, and partly because they give information as to the direction of pressure.

PORPHYRITIC GRANITE. — Studies of the crystallines show a grouping of material in concentric rings around a nucleus. The porphyritic granite of Littleton may constitute the nucleus around which a finer-grained granite is enwrapped. The chief part of the area is towards the north, outside of the town limits. The interior core is an oval-shaped area of about four square miles in the adjacent corners of Littleton, Whitefield, Bethlehem, and Dalton. The rock is of medium grain, filled with crystals, up to two inches in length, of potash feldspar (orthoclase), whence the significance of the term “porphyritic” or “spotted.” The feldspars are often twinned, the plane of twinning corresponding with that of the foliation of the mica. The reversal of one-half of the twin changes the position of the cleavage planes, so that one part is clearly, and the other indifferently, reflected, and thus the crystals are conspicuous. Part of the rock is foliated, in which case the large crystals are disposed along the foliation planes; other portions show no arrangement of any of the minerals. The ground mass is made up of the three usual mineral constituents of granite, — quartz, feldspar, and mica. The mica is commonly the black variety, called *biotite*; but in Littleton there is more than the usual supply of the white variety known as *muscovite*. Oligoclase may be present as well as orthoclase for the feldspar. The quartz is always amorphous, so far as I have observed. Where the large crystals of feldspar are badly formed, they may be somewhat lenticular in shape, and the attendant mica disposed like eyebrows, so that one may imagine a ledge filled with staring eyes. Noticing this peculiarity, the Germans call this rock the *Augen*, — *eye gneiss*. There is often, also, a considerable iron in the rock, whose decay imparts a rusty color to the ledges.

In Europe and Canada the augen gneiss has been ranked as Archean. For that reason I called this rock Laurentian (=Archean) in my report, and represented that the thirty areas of it known to exist in New Hampshire might have been the primitive land areas of the continent. With a changed view of its origin, it may still be regarded as thus ancient in some localities, for

igneous rocks constituted the whole of the Archean terranes. This rock has also been erupted in post-Archean times, so that by the mineral character alone we are not warranted in deciding upon the age.

At Alder Brook, in company with the late Dr. T. Sterry Hunt, I made an attempt to determine the possible disposal of the minerals in certain planes, which might be termed strata. We found, first, nearly horizontal masses with no variation of mineral composition; second, an alternation of coarse gneisses; third, fine feldspathic layers, more irregular than the others. The predominating dip of these several sheets was 75° S. 40° E. It seemed at the time as if this arrangement might correspond to stratification; and if so, it would represent a downward dip reappearing on the north flank of Mount Lafayette, thus constituting a synclinal axis; and it was so figured in the report (Vol. II., Plate VI., Fig. 7).

At this same locality the rock has been much decomposed, so that when a ledge has been cut through it is found to be made up of loose blocks, as the softening and removal of the granite adjacent to the joints has separated the fragments from union with one another. To the west of Alder Brook is a precipitous hill of the porphyritic granite, very conspicuous as seen from the village of Bethlehem. It is known as Bald Hill, and is immediately adjacent to Mann's Hill. The foliation at the back of Bald has the dip of 70° N. 75° W., making an anticlinal with that at Alder Brook, and nearly parallel with the position of the adjacent mica schist. In the low ground towards Round Pond the boulders of this rock are extremely numerous.

GRANITIC GNEISS.—The porphyritic granite is encircled by a granitic gneiss, which represents the southwest terminus of a large terrane reaching as far as Milan. A band of mica schist interrupts the direct continuity of this gneiss from Mann's Hill; but it is supposed to exist beneath the schist. The most important portion of this rock underlies the village of Littleton north of the Ammonoosuc, extending west as far as to the cemetery. The dip of the foliation is greater on Mann's Hill than upon Oak Hill or in the village, it being 75° in a general northwesterly direction in the former, and about 40° in the latter locality. At the reservoir on Palmer Brook there is a ledge with the high dip, also along the railroad near Apthorp. Hornblendic layers occur on Mann's Hill; and both there and in the village pieces of mica schist appear included in the gneiss. Hence the granite is probably of later origin than the adjacent Coös mica schists, from which the frag-

ments have been torn. Further study may indicate the existence of a mass of granite, the porphyritic inside and the gneissic outside, which is independent of the larger mass in Whitefield and Jefferson. The Littleton gneiss was ranked in the State Report as a part of the common or Lake Winnipiseogee gneiss.

PROTOGENE OR BETHLEHEM GRANITE. — Quite early in our studies it was found convenient to give a local name to a mass of granitic rock sparingly foliated, and characterized by the presence of chlorite, talc, rotten mica, or other decomposition products. This rock is protogene, and the local name of *Bethlehem* was applied to it. The area touches Littleton in its southern corner. To properly understand the structure one needs to note that the mass has an elliptic shape, occupying the chief parts of Bethlehem and Carroll, and that the foliated planes dip at a high angle several degrees west of north. It was supposed in the Report, following the idea of a sedimentary origin, that the structure was that of an inverted synclinal, the dip being somewhat to the west of north. The dip is vertical with the strike, N. 58° E. along the railroad opposite Apthorp, 75° N. W. on the east side of Mount Eustis, 55° N. 20' W. at South Littleton, and a few degrees less at North Lisbon. At the southwest part of the area are inclusions or pieces of dark schists imbedded in the granite. They are apparently pieces of the bordering mica schists, broken off by the disturbances connected with the intrusion of the granite. It is presumed that many of the inclusions have been incorporated into the liquid mass, while all have been more or less altered by the action of the heat.

According to the report, there are four leading varieties of rock in this area: First, granite made reddish by abundant flesh-colored orthoclase, with a chloritic mineral in place of mica and amorphous quartz; second, fine-grained gneiss; third, gneiss with porphyritic crystals of feldspar; fourth, mica or chlorite schist with very little feldspar or quartz. Magnetite and epidote are not uncommon. Dr. Hawes remarks, concerning these protogenes, that in the thin sections some hornblende may be seen, and that the little plagioclase present is much altered. Sometimes a handsome variety carries green spots, in the centre of which are scales of biotite, indicating that the latter was the original mineral. The green decomposition product is epidote.

This granite has been thought to represent Laurentian gneiss. Prof. J. D. Dana, who was a thorough advocate of a late age for most of the rocks of this vicinity, was convinced that some of the gneisses along the railroad must have been Laurentian because of

their resemblance to known rocks of this age elsewhere. As will be seen later, the Niagara and related rocks have been uptilted by this granite at South Littleton and North Lisbon; hence it will be proper now to modify the earlier conclusion. The rock has never been stratified, and the pressure inducing foliation was directed in a direction between north and northwest.

HYDRO-MICA SCHIST GROUP.—If one examines the geological map of northern New England and Canada he will observe two important belts of green schistose rocks centrally situated. One starts in southern Massachusetts west of Connecticut River, passes almost directly north through Vermont just east of the Green Mountains into Canada, and then turns easterly, continuing to Gaspé. This terrane is repeated upon the west side of the Green Mountains in northern Vermont and Canada. The second belt commences near Bellows Falls, continues almost uninterruptedly along Connecticut River to Woodsville, where it expands and increases till it occupies nearly the whole breadth of northern New Hampshire. From thence it continues to the Gulf of St. Lawrence parallel to the other area. Littleton is situated upon this second belt.

The rocks consist of hydro-mica and chlorite schists, sandstones, quartzites, argillitic schists, bands of argillite, dolomites, limestones, diorites, protogenes, hornblendites, and some others. The whole assemblage has a greenish tint, insomuch that Dr. S. W. Hawes was disposed to restore the old name of *Greenstones* for the group. For local names the usage has been varied. Sir W. E. Logan proposed three terms, — *Levis*, *Lauzon*, and *Sillery*, — all of which combined were spoken of as the *Quebec* group. The first three of these names I applied to the rocks of the first belt, in the published New Hampshire State map, as they stretched southward into Vermont from Canada, following Logan. It appeared to the later Canadian geologists that Logan misunderstood the structure of these rocks in Canada, and hence his successors have explained the order of arrangement differently. They avoid the use of the three local names, and speak of the terrane as *Cambrian* and to some extent *pre-Cambrian*. I made no attempt to correlate Logan's divisions in the eastern belt, but devised new local names; calling the lower part *Lisbon*, the upper *Lyman*, and a still third band of *auriferous conglomerate*. In the first two annual reports I used the general name of "Quebec group" for these greenstones, recognizing the equivalency of the rocks with those farther west. I think nothing more is said about this area before the preparation of the final report, where the name *Huro-*

nian appears. In the first blush after the discovery of Logan's misinterpretation, the attempt was made to correlate these green rocks with their petrographical equivalents located upon the north side of Lake Huron, to which Logan had already given the local name of the lake. For this reference I was obliged to follow the leadings of certain Canadian geologists who were familiar with the rocks of the eastern townships of Canada, as well as with those farther west. At the present date those who have been studying these rocks, both to the north and south of New Hampshire, are divided in their views of age, — some finding them to be Cambrian, and others, following essentially the early opinions of Logan, making them to be Lower Silurian. The absence of fossils prevents a closer correlation.

Petrographical studies enable us to separate, as either of igneous or metamorphic origin, quite a number of the rocks named above. They are the diorites, protogenes, and hornblendites. They had at first been esteemed as essential constituents of the group, particularly as they are also abundant in the Huronian country. They are wanting in much of western Massachusetts, so that it is natural that the same strata there should be regarded as of a different age. Hence the presence of either of these igneous rocks shows us simply what kind of agency has been at work, and they do not necessitate reference to any particular age. These igneous rocks were grouped with the Lisbon terrane in my report. Now they might receive a separate coloration, as of a different class.

Quite early in my studies I found the name applied by my predecessors to this central belt to be a misnomer. They were called *talcose slates*, having talc for its essential constituent. Now talc is a hydrous magnesium silicate. Average samples of these greenish greasy rocks in Vermont were found to be hydrous aluminum silicates, and hence not properly talcose. Unfortunately, the precise mineral present is not well known, because it is so indefinite in composition, so that it is not easy to find a name to take the place of talc. Under these circumstances Prof. J. D. Dana proposed the term *hydro-mica* instead of talc; and for the present it may be employed when speaking of the petrographical nature of the rock.

The Lisbon group includes properly the various greenish schists and sandstones, the latter commonly altered. The Lyman group was intended to designate, first, a massive light-colored or white schist, whose original color must have been some shade of drab; second, a slaty rock of related color, with an argillaceous odor;

Dr. Hawes called them argillitic schists. The white schists are often entirely composed of elongated pebbles.

More than half of the township of Littleton is underlaid by these green and argillitic schists. My published map represents the whole of the northeast portion of the town, from Mann's Hill across to Connecticut River, as composed of the Lyman rock. A broad strip of it makes up Palmer and Wheeler hills, and passes southwesterly through Mormon Hill and through the town of Lyman. Two or three other short areas of the Lyman group appear north of Partridge Pond, and the continuation of Gardner Mountain across to Waterford, Vt. The space enveloped by the Gardner Mountain and Palmer Hill ranges is referred to the Lisbon group, occupying rather a larger space than the other division. I cannot pretend that these divisions are marked by hard and fast lines, nor that the structure is well understood. Perhaps a few words about the character of several of the bands may best describe the geology of this terrane, largely quoted from the State Report.

The western half of Littleton consists mostly of the Lisbon group. This development is characterized by the predominance of chloritic and green schists. The Gardner Mountain area is characterized by the presence of cupreous schists, in two localities, two hundred rods apart, which at one time were exploited for copper. The rocks of this mountain range are partly hydro-micaceous and partly argillitic, dipping 60° S. 70° E. Similar schists, standing vertically, are associated at the Quint copper mine, about a mile and a half east of the eastern Gardner Mountain belt. In general, the rocks from J. Bowman's, near Lower Waterford bridge, to W. Redwood's, a mile and three quarters east of the Upper Waterford bridge, are chloritic, with seams of calcite, usually perpendicular, with a northeast strike. At Mullikin's saw-mill the green schists are traversed by a trap dike, and some of the rock is conglomeratic, of the Lyman group. The rocks are similar on a hilly road from the saw-mill to near the slate quarry, or as far east as to D. Robbins' house. The green schists are continuous southerly from the saw-mill to the heights east of Partridge Pond. The map also shows a range of the Lyman schist northerly from Partridge Pond to Connecticut River. Near the town-house¹ is the boundary between the grayish green schists and protogene. The former may be two miles wide along the main road from the village to West Littleton. Other outcrops of these schists appear between the town-house

¹ Old town-house near Fitch place.

and the Wheeler Hill cemetery. Bands of slate holding large nodules or bosses of quartzite occur east of Wheeler's. There are hydro-micaceous schists on the west side of Wheeler Hill. Near the summit it is more argillitic, carrying a little copper, with bands of a chocolate color. There are more green schists on the south side of Cow Brook, near R. Moore's, with the strike N. 50° E.; also farther east upon Palmer Hill of the county map. The same schists occur on both south and north sides of Morse Hill.

A well-marked band of the Lyman schists enters Littleton from the northeast corner of Lyman. The rock is apparently a conglomerate, in which the pebbles have been elongated, and display their fragmental character only upon weathering. It adjoins the fossiliferous strata at the head of the middle branch of Mullikin's or Rankin's Brook. To the west and north of the lime quarries, near Parker's Observatory, this same schist is well developed; and later theoretical views would make us regard it as a silicified argillite, much like the novaculite of Fitch Hill.

The State map represents another Lisbon area along the east side of Blueberry Mountain, reaching nearly to Palmer Mountain. Portions of it have been covered by the alluvial deposits of the Ammonoosuc River. They pass into what was called the "Swift Water series," in the report on the hills west of South Littleton.

IGNEOUS BANDS CONNECTED WITH THE HYDRO-MICA SCHISTS. — These are the hornblendites, diorites, and protogenes, formerly thought to have been stratified and essential constituents of the terrane. The last-named occupies the most space. It may be seen in the notch north of Fitch Hill along the Waterford road, between one and two miles from the post-office. It may also be followed up Fitch Hill in contact with the fossiliferous limestone, and along the western base of the Blueberry range for another mile. It is abundant the first half of the road up to Kilburn's Crag. It occurs also on the east side of Blueberry Mountain back of the J. K. Corey place.

Diorite adjoins the Niagara slates on Fitch Hill, and has altered them at the point of contact into novaculite. It follows the ridge southerly, and is fully two hundred feet wide where it crosses the road up to Kilburn's Crag, between sandstone and slate. There is a little hornblendite along the east flank of the Blueberry range, which is the obvious continuation of the more extensive nodular outcrops of the same material in the central* and north parts of Lisbon. The true character of these igneous rocks will be discussed farther on.

SILURIAN AND DEVONIAN STRATA. — Under this heading are included the Coös mica schist and quartzite, the Niagara limestones and slates, sandstones and argillites. No fossils have yet been discovered in the mica schists. The name of *Coös* was applied to an associated group of quartzites and mica schists with staurolite, extending entirely through the State from Massachusetts to Canada. They are first seen in the hill west from South Littleton, whence it crosses the Ammonoosuc and rises into Mount Eustis. It then sinks beneath the river again at Apthorp, and rises into Mann's Hill, adjoining the porphyritic granite, and thence entering Dalton. As fragments of these schists have been included in the several granites, it is believed the group was elevated at the time of the protrusion of the igneous masses. A greater elevation of the strata seems to have been thus originated in the hill west from South Littleton. The strata usually dip seventy degrees in a northwesterly direction, with variations due to the proximity of the granites. Micaceous quartzites abound in the bed of the Ammonoosuc in the village and near Apthorp. The exact junction of the mica schist and granite may be seen in a railroad cut east of Apthorp. Staurolite is present in it upon Mann's Hill, where are also bosses of hornblendite and granite veins. Near the Dalton line some of the beds are calcareous. A little to the south of Littleton stauroliferous argillites show themselves. These were regarded as belonging to the same Coös series in the State Report. The mica schists with staurolite border the protogene granite on its south side, extending to the edge of Bethlehem along Indian Brook, and are supposed to be identical with the Mount Eustis belt, but pushed southerly by the intrusion of the protogene.

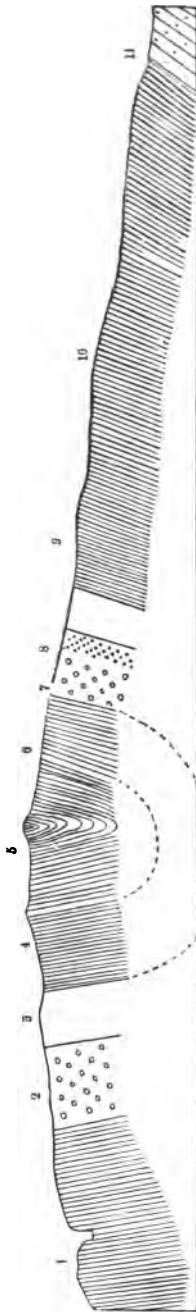
SWIFT WATER SERIES. — Adjoining the mica schist on the west in the south part of the town are considerable thicknesses of a whitish mica schist with siliceous layers, not readily referable either to the Coös or Lyman groups. They are of more consequence in the next town southerly. In the printed report they were referred to the Swift Water division of the hydro-mica schists. If one follows the south line of the town westerly from the railroad, he finds these schists exposed west of the Ammonoosuc adjoining the Coös rocks. They are best developed where the road crosses the town line, near the P. H. Paddleford place on top of the hill. Some of the schists are chloritic, associated with conglomerates made up of flattened pebbles interstratified with hornblende schists. These are followed on the west by the indeterminate whitish schists. These all have a very high dip north-

west. They occupy a sort of plateau, and dark slates succeed them as you climb Blueberry Mountain. Farther north and south a sandstone, limestone, and conglomerate outcrop between the schists and dark slates. The reason of their absence at the town line is unexplained.

SYNCLINAL STRUCTURE OF BLUEBERRY MOUNTAIN. — In the printed report considerations were presented in the attempt to understand the relations of the argillites of Blueberry Mountain to the adjoining rocks, to show that they were of Cambrian age, and that the fossiliferous limestones flanking them on both sides must be limited outliers, although apparently dipping into the mountain in the same manner. Our recent studies satisfy us that the structure of Blueberry Mountain is truly synclinal; and hence these fossiliferous rocks must be older, and as they are of Niagara age, the slates must be still newer, — Upper Silurian or Devonian, perhaps best expressed by the term "Helderberg." As to the structure, the terrane in Bath and Lyman is admittedly synclinal; so that no change in it would be looked for in Littleton. Secondly, sections are now complete across the Blueberry range near the south town line, from the head waters of Mullikin's Brook to South Littleton, from the slate quarry to the Ammonoosuc River, and farther north, all of which seem to involve the basin structure. Thirdly, the disappearance of most of the slate in the notch for the Waterford road, two miles west of the village, and its reappearance farther north, seem to imply the removal of the upper terrane by erosion. If the structure were anticlinal, the breadth of the slate should be greatest at the lowest point.

Granting the correctness of this deduction, the order of the rocks from below up should be after the Swift Water series: (1) limestone; (2) a sandstone; (3) coarse conglomerate; (4) bluish and black slates. Localities displaying this order are, for the east side, the farm occupied formerly by J. K. Corey; and for the west side, the descent from the summit of Blueberry Mountain where it is traversed by a carriage road in a southwest direction. Annexed is Fig. 42 of the State Report, showing the order and position of the several members between the slate quarry and the Ammonoosuc River.

SANDSTONE. — The part readily recognized as a sandstone either shows distinct grains or has been somewhat vitrified. At the Corey farm it assumes the more glassy form about a quarter of a mile west of the site of the buildings. This condition may, perhaps, be explained by the proximity of considerable protogene farther west. The sedimentary character is well shown on top



SECTION FROM SLATE QUARRY TO THE AMMONOOSUC RIVER.

1. Slate quarry. 2. Conglomerate. 3. Greenish schist. 4-6. Dark slate. 5. Light-colored sandstone. 7. Conglomerate. 8. Limestone. 9. J. K. Corey's house.
10. Swift water schist. 11. Green schist at the Ammonoosuc River.

of the peak south from Mr. Fitch's house and north of Kilburn's Crag. Passing from this summit easterly to Parker Brook at the road-crossing, the same rock appears; also upon the east side of the valley west of the cemetery. There may be a fault between these exposures, as one side seems to have been thrown out of continuity with the other. Next this rock appears as a buhrstone, less than a mile on the road north from the cemetery. It may be traced thence to the top of the hill near Burnham's or Clark's limestone beds; also down the hill near the old limekilns near Mr. Clark's. As a somewhat similar rock crops out on the north side of Mann's Hill, near the Dalton line, it may be that this band is continuous to that point over the high mountain. On the west side of Blueberry Mountain this sandrock has been noticed near Mr. Fitch's on the road up Kilburn's Crag, and in the valley of Mullikin's Brook, near the south town line.

LIMESTONE. — The most important of these members is the limestone, because it is fossiliferous. It accompanies the sandstone from the Corey farm to Clark's quarry, and has yielded fossils in several localities, as at the Corey farm, an old quarry near Parker Brook, near Jackson place, and at Clark's quarries, where the first discoveries were made. The same rock is traceable from the Waterford road over Fitch Hill, near the slate quarry, and so on to the very town line to the west of E. Swett's house in the low grounds. The following fossils have been recognized in it, chiefly from Fitch Hill: *Favosites basaltica*, *F. Niagarensis*, *Zaphrentis*, *Astrocerium venustum*, *Halysites catenulatus*, *Pentamerus Nysius*, a *Lingula*, crinoidal fragments, a gasteropod, *Dalmania limulurus*, and fragments of a *Lichas*.

In starting from Mr. Fitch's house the first rock seen is the protogene, which may be fol-

lowed a quarter of a mile to close contact with the limestone. This may be fifty feet in thickness, carrying corals and the *Pentamerus*. This is followed by a slate forty feet thick, in which the *Dalmania* occurs. It is replaced by as great a thickness of a friable, coarse sandstone, slightly reminding one of the Oriskany sandstone of New York, the quartz pebbles being of the size of kernels of Indian corn. Continuing up the hill into the edge of the woodland, the rock is what Hawes called *novaculite*,¹ — a somewhat bluish, compact, siliceous rock. It appears to be simply the Niagara slate, altered by contact with an igneous diorite, which continues for several rods, nearly to the top of the hill, where are other exposures of sandstone weathering white. Some parts of this rock suggest the presence of a metamorphic change, consisting of the enlargement of grains of feldspar by a crystalline growth since their original deposition. All the stratified rocks named may, for the present, be classed with the Niagara. They dip mostly in a southeasterly direction at a very high angle.

The whole of the slope of Fitch Hill towards the village has been traversed, and one may see there samples of all the rocks named above, with fossils in the limestones. Fossils occur, also, on the east side of Parker Brook, and at the old Clark quarries upon Farr Hill. A careful search will undoubtedly add to the list of localities, and to the number of fossils represented as well.

COARSE CONGLOMERATE. — On both sides of Blueberry Mountain, at several localities, there is a conglomerate whose pebbles are ordinarily about the size of hens' eggs. Just above the slate quarry is one of these exposures, which is thus described in the printed Report:² "The paste is the slate of the quarry. One pebble

¹ "This rock is light-gray in color, massive, and so fine in its texture, and so homogeneous, that no ingredient can be microscopically detected. It looks like a gray felsite, and like felsite it fuses before the blow-pipe. A study of a thin section shows that it is an excessively fine-grained mixture of much quartz and little orthoclase, among which the little fibrous and scaly crystals of mica that characterize the argillitic mica schists are thickly scattered; but these scales are much smaller, and do not constitute an ingredient of any importance. Grains of calcite are also seen. The constituent minerals bear a recrystallized character, and none of them appear fragmental. The rock has, therefore, all the characters of argillitic mica schist; and the massive condition is due to the excessive amount and fineness of the quartz, and the small amount of the micaceous constituent. Its fusibility, which first caused it to be called felsite, is in part due to the calcite, which forms a flux for the silica, and in part to the orthoclase, for it is well known that a mixture of quartz and orthoclase will fuse as easily as orthoclase alone. . . . This is the novaculite, or oil stone, that is so highly prized for sharpening tools." (Hawes, *Geology of New Hampshire*, Vol. III. p. 222.)

² *Geology of New Hampshire*, Vol. II. p. 333.

is a foot long. Siliceous fragments of a dark color predominate, which seem to have been derived from the Lisbon group, as also have been a few greenish chloritic bits. Others, and possibly the greater portion, show resemblances to the compact feldspar of the porphyry group. There are small bits of slate like that occurring near the east base of the mountain near the Ammonoosuc River. A similar rock is found on the east side of the range, as shown in the figure; also on the west side of the mountain near the Lyman town line. Outside of the town limits the same rock is well developed, as at North Lisbon, and perhaps in the northeast part of Lyman. The question has arisen whether this belt may not be the same with the Auriferous conglomerate of Lyman and Bath; but its answer cannot be obtained by studies within the limits of Littleton. It is certainly an important member of the Blueberry Mountain series, but one likely to be very variable in coarseness.

SLATES OR ARGILLITES.—The most important range is the general mass of Blueberry Mountain, which has a synclinal structure. One variety is almost black; the more common has the color known as slaty; and a third is noted for carrying large crystals of calcite, very often removed at the surface, so that the rock is conspicuous by the presence of numerous rhombohedral holes. Other parts of the slate carry conspicuous crystals of pyrites.

On the east side of Parker Brook the slate begins to increase in amount, with a northeasterly strike, and either vertical or leaning slightly to the southeast. The beginning of changes is seen in an infusion of silica, which has hardened the slate, and given rise to veins of quartz, and the lining of cavities with handsome crystals of quartz more or less geodic. The quartz increases in amount in going easterly till the buhrstone is reached,—which is really a similar rock,—an infusion of sandstone with silica. One needs only to recall the geysers of the Yellowstone sending up water charged with silica to understand how that a similar hot alkaline water once penetrated these slates and sandstones in Littleton, and thus produced the quartz crystals and the altered rocks. Farther north, a section across the slates displays a recognizable synclinal structure. Upon Farr Hill fossils resembling *Chondrites* have been noted. These are allied to fucoidal seaweeds. Smaller slate areas are noted upon Morse Hill, in one of which, at least, slate was quarried twenty-five or thirty years since by Mr. Richard Smith. This rock seems to thin out near the town line, but to reappear in greater force in Dalton Mountain. It is a question whether the corneous rocks, so abundant in the northeast sec-

tion of the town, are not really argillites altered by heat, like the novaculite of Fitch Hill.

TRAP DIKES. — In Volume III. of the State Report a beginning is made in the study of rocks with the microscope, using the latest methods. Of the rocks thus described, the eruptive diabases and diorites are quite interesting. These are known as *trap*, being fine-grained eruptive masses that have filled fissures in the earth. Several of these dikes exist in Littleton, as at Mullikin's saw-mill, and upon Mann's Hill, and in boulders whose source is not always known. The diabase is a mixture of the mineral labradorite, augite, and titanite or magnetic iron. When the iron abounds, the color is dark-gray or black; if the feldspar predominates, it will be a light-gray greenish when chlorite is plenty, and a bluish-black when stained by manganese. The minerals are crystalline, and too small to be determined without a compound microscope. In order that they may be thus examined, it is necessary to grind down slices of the rock till it is transparent, or thin enough to allow the eye to discern newspaper print through it. A further study of the minerals present proves that these diabases have been subjected to great changes, sometimes called metasomatic or metamorphic, because the minerals of the original fused mass have been changed chemically. Thus the augite may become hornblende and chlorite. Epidote and calcite may have been derived from the labradorite. Mica and needles of apatite are sometimes present as accessories. These changes were apparently effected under conditions not now existing, — perhaps when heated vapors, chiefly steam, permeated the ledges so as to allow molecular interchanges. The rock is now apparently fresh, — at least it shows no exterior signs of decay; but the presence of the altered minerals — calcite, epidote, and hornblende — is absolute proof of a change analogous to decomposition.

The dikes mentioned above are supposed to be diabase. Boulders of two varieties of it are common. One is of *anorthic* diabase whose source has been recognized in Concord, Vt., just across the river. It is porphyritic; that is, has many large crystals scattered through a finer mass of the same or analogous material. The large crystals are *anorthite*, a lime-feldspar, a substance more infusible than the ordinary constituents of diabase, and hence supposed to have been the first mineral to crystallize from the fused magma. Because of subsequent alteration this anorthite has become *saussurite*, — a translucent waxy substance, seen under high magnifying power to be a mere aggregate of fine needles. Calcite is also present.

A very few boulders of diabase have been found on Farr Hill in which there are crystals of biotite an inch in length. It has not been studied, and its source has not yet been ascertained.

A handsome diorite is found in boulders about South Littleton and North Lisbon. This is a crystalline granular mixture of a triclinic feldspar, hornblende, and an oxide of iron, either magnetite or ilmenite. The hornblende is in porphyritic crystals, and is directly associated with augite, so as to prove the derivation of the former from the latter. The hornblende is entirely fresh, while the augite is decayed if not dissolved away, and its substance replaced by decomposition products, such as chlorite, epidote, and calcite. There is considerable feldspar present, though considerably decomposed. The rock is quite handsome, and one of the best of the traps found anywhere in the State to illustrate the origin of the hornblende.

There are other diorites and hornblende rocks, or amphibolites, still more common in Littleton, that have been considered in connection with the hydro-mica schists. Dr. Hawes has described some of them in his report, and seems inclined to regard them as of metamorphic rather than of a purely igneous origin. In examining sections of the unquestioned eruptive diorites the hornblende shows sharp, definite plane surfaces, or if irregular it possesses well-defined outlines. It is deeply colored, black, is strongly dichroic, and does not give brilliant polarization colors. Opposed to this, the hornblende of the metamorphic diorites is found in diffuse and loose forms, fringed masses, aggregates of needles and minute disseminated crystals, less deeply colored; is light green in thin sections and not so dichroic, and gives brilliant polarization colors. The first is the basaltic and the second the common variety of hornblende. These differences were thought by Dr. Hawes to be due to a thorough igneous fusion in the first, and to a gentle moist heat in the second case, the one being of igneous and the second of metamorphic origin.

Two analyses of the Littleton hornblende are worth examination. The precise locality of the first is not given; that of the second is from Fitch Hill. The first is that variety of hornblende called pargasite, and which oft-repeated analyses have shown to be the common hornblende of green diorites in all localities. It is not a mixture of hornblende and pyroxene, as some have supposed.

	1	2
Silica	49.08	45.46
Alumina	13.72	16.57
Iron sesquioxide		.36
Iron protoxide	9.84	9.40
Manganese protoxide	.40	.20
Lime	11.22	8.01
Magnesia	11.96	10.34
Potash		1.20
Soda	2.40	2.55
Titanic acid		1.20
Water	.90	3.93
Carbonic acid		1.02
	99.47	100.34

ECONOMIC GEOLOGY.

The following substances have been or can be quarried or mined for economic purposes in the town of Littleton : Copper, roofing-slate, novaculite, diorite for macadamizing roads, limestone, clay for bricks, granite and massive rocks for rough stone-work.

COPPER. — Twenty-five or thirty years ago considerable interest was manifested in the exploitation of ores of copper both in Littleton and the adjoining towns. The rock yielding this metal is the hydro-mica schist group, particularly the lower division, hydro-mica, chlorite, and argillitic schists. Gardner's Mountain, to the south, carries veins which were worked for several years, and it was the continuation of this range into Littleton that furnished the same metal. The ore is chalcopyrite, the common yellow copper sulphuret, consisting of copper, 34.6 ; sulphur, 34.9 ; iron, 30.5=100. Through decomposition the green carbonate and black oxide of copper are occasionally seen. The associated ores are argentiferous galena, zinc blende, and pyrrhotite. Some of these sulphurets are sparingly auriferous.

The veins usually consist of belts of intermingled pyritiferous, cupriferous, and siliceous layers, each one of no great extent, but the whole practically a vein several feet wide. It has been a question whether these belts are simply cupriferous schists, or whether there may be a nucleal fissure vein in the midst of the mass. The more excavations have been made the better is the evidence afforded of the accumulation of the ores along fissures.

Many people speak of a vein as continuous for miles in a uniform direction. I have thought the continuity is to be seen in the presence of a series of lenticular patches, not continuous on abso-

lutely the same plane, but overlapping in closely contiguous sheets. Hence what seems to be the same vein in adjacent lots is rather a series of flattened bunches arranged *en échelon*.

Upon the land of J. A. Albee, in the southwest part of the town, is a cupreous vein that has been worked more or less. The principal outcrops are on the northern extension of Gardner's Mountain, several hundred feet above the Connecticut and well situated for drainage. There seem to be three distinct metaliferous belts, separated by greenish sandstones, and indicated superficially by yellowish-brown ferruginous stains. If these are penetrated quite deeply below the surface, copper ore invariably shows itself. A shaft had been sunk to the depth of seventy-eight feet in one of these belts, and a pile of ore containing by estimate one hundred tons was visible that had been mined. It was a mixture of slate and quartz with bright-yellow chalcopyrite and pyrrhotite, the latter mineral being the more abundant near the surface. It was said that the copper-bearing vein varied in width in the shaft from six inches to eight feet, and that the ore near the surface carried one and seven-eighths per cent of copper, and twenty-eight per cent at the depth of sixty feet. A company proposed to work this property in 1877 under the name of Gardner Mountain Copper Company.

Four thousand feet east of this property, upon a ridge, and separated by a valley from 250 to 300 feet deep, is another vein, upon the land of Mr. Little, to which the name of Gregory Mining Company had been given in 1877. The chalcopyrite obtained here is quite pure, and makes brilliant specimens. The cupreous schists are quite extensive. The width had not been determined when the shafts were being sunk, as the object had been to sink as deep as possible without reference to bounds. Large piles of ore were scattered about the premises, and one lot of twelve tons of seven per cent ore had been sold. Work was carried on here for several months.

A mile or two east of the Gregory is situated the Quint, or White Mountain, mine. No copper property in this region had been so thoroughly exploited as this in 1869; several buildings having been erected for shaft-house, whim, dressing-sheds, etc., and the main shaft had been sunk one hundred feet. Work was not being prosecuted at the time of my visit, nor has it been subsequently, to my knowledge. The vein must be from six to eight feet wide, consisting of white quartz with chalcopyrite, pyrite, ankerite, and chlorite disseminated through it. Very beautiful hand specimens can be obtained.

The copper industry has not proved a success in Littleton, at least the proprietors have ceased to work their properties. A part of the difficulty arises from the fact that the greater deposits of an easier ore to work in Michigan and Montana have lowered the price of the product so that it is not profitable to reduce the refractory sulphuret compounds of the East.

ROOFING SLATE. — This rock has been quarried in the town, and a few remarks in the State Report are fully applicable to them now: "In Littleton there are two openings in the north part of the town, upon the adjacent farms of Richard Smith and Mr. Bachelder. The band of rock suitable for working is nearly an eighth of a mile wide, and the principal opening has been excavated to the depth of twenty to twenty-five feet. Bachelder's quarry is the farthest from the road, and has had the most work done upon it. The strata are vertical, and as the outcrops are on a hill, the facilities for drainage are good, and working surfaces can be obtained one hundred feet in depth. The rock seemed to be free from pyrites, was soft, but does not cleave so thin as the slate from Maine. About two miles westerly from Littleton village is a large excavation on the west side of Blueberry Mountain range, high up, and well situated for mining. The opening is about two hundred feet long and fifty deep, presenting a face of these dimensions. There is a cross-cut into this opening, through which the slates are transported over a tramway. Several houses have been erected for the accommodation of the workmen, and a large amount of rock has been already removed. The samples of slate stored for shipment appear to be of excellent quality. The color is a bright dark-blue, and the stone soft and apparently durable. The face corresponds with the slope of the hill, so that the position is a favorable one for mining, the slate standing about perpendicular. About 1865 an attempt was made to form a company to work the quarry, but for some reason it failed. Many of the layers are filled with cubical crystals of pyrites, and it is likely that the abundance of this mineral discouraged the proprietors, preventing the carrying on of a large business."¹

MISCELLANEOUS. — Of the other materials mentioned, no effort has ever been made to utilize the novaculite, or oil stone, nor the diorite for macadamizing roads. Of late, in conformity with the desire to improve our highways, efforts have been made to search for the best material for "road metal," as it is popularly termed. The best rock known for this purpose is the "trap," and an excellent and extensive mass of it is what has been described as

¹ Geology of New Hampshire, Part V. pp. 81, 82.

the diorite of Blueberry Mountain. When the time comes for the use of pulverized diorite for the highways, Littleton will be found to possess an abundant supply of first-class material.

Limestone has been used for the manufacture of quicklime in Parker Brook valley and on Farr Hill. The material is still accessible at these localities and at others, sufficiently valuable for local purposes. Clay has been burned for bricks at Parker Brook, and may be found elsewhere in the town, though not abundant. Rock suitable for rough stone-work is plenty. A dwelling-house in West Littleton has been constructed of material — granite — split out from the adjacent boulders.

THE ICE AGE.

This sketch would not be complete without a reference to the phenomena illustrative of the former presence of an enormous mass of ice over all this section of country of glacial character. I have said, and still affirm, that every mountain and every valley of New Hampshire, when carefully examined, will afford evidences of the presence of this ice. For a full presentation of the subject I will refer to Part IV. of the *Geology of New Hampshire*; being content now to mention only a few features readily seen close at hand.

Two classes of phenomena must be considered when we study the work accomplished by the ice: first, the smoothing down of the ledges; and, second, the accumulation of the rubbish knocked off, carried, and finally dropped. On the next page is a meagre list of the observations upon the directions taken by the striæ in connection with the smoothing in different parts of the town. The courses have been corrected for the variation of the needle, and the names are mostly those printed upon the old county map.

Two conclusions seem to arise from this presentation: First, the course S. 17° W. is the most common, and occupies most of the space west of the Blueberry range; second, the most easterly direction is displayed near the beginning of the ascent to Kilburn's Crag and in the Parker Brook valley, in S. 20° and 25° E. The normal direction of the movement, over the tops of the White and other mountains in northern New England, is to the southeast, which may be taken to correspond with the most eastern course in Littleton. Furthermore, it is believed from data elsewhere obtained that this southeastern course represents the time when the ice was greatest in amount in what may be called the culmination of the glacial period. Presumably the whole of Littleton was oc-

cupied by ice moving southeasterly at that time. If so, we should expect to find occasionally striæ pointing in that direction, while most of them had been obliterated by the later movement about S. 20° W. Such a remnant is the case cited above, of S. 20° E. It is in the midst of striæ pointing in another direction.

It is a conspicuous fact that all through the valley of the Connecticut most of the striæ correspond in direction with the trend of the stream, which varies from S. 10° to 20° W. It has been explained by saying that the pressure upon the ice from upstream

Locality.	True Course.	Rock.
Mann's Hill	S. 12° W. and S. 17° W.	Mica schist
Mann's Hill, height of land in road . .	S.	Lyman group
A. Annis	S. 17° W.	Mica schist
Near Dalton line	S. 17° W.	Lyman group
W. Fisk	S. 5° E.	Slate
R. Moore	S. 25° W.	S. of Cow Brook
Ridge between Cow and Parker brooks .	S. 17° W.	Chlorite schist
Farr Hill, near point	S. 30° W.	Slate
Mullikin's Saw-mill	S. 17° W.	Hydro-mica schist
East of S. Wheeler's hill	S. 17° W.	" "
A. P. Hubbard	S. 28° W.	Slate
West side Fitch Hill	S. 5° E.	Protogene
Kilburn's Crag, near top	S. 28° W.	Slate
" " quarter way down road . .	S. 26° W.	"
" " near base of road	S. 10° W. and S. 20° E.	Protogene
East side of Parker Brook, near old lime-kiln near Jackson place	S. 25° E.	Quartzite
East side of Parker Brook, higher up hill, E. side	S. 5° E.	Slate
Waterford Road, 1½ miles west of village	S. 7° E.	Protogene
Corey's, South Littleton	S. 7° E.	Sandstone

caused it to move in the direction of least resistance, that is, down the valley. Others prefer to say that the valley movement was connected with a local glacier in a later period of the ice action. Such is the view taken in the State Report; and for the region of Littleton this conclusion has been illustrated by the movement down the Ammonoosuc from near Fabyan's, transporting the peculiar rocks occurring above that hostelry for several miles toward Littleton. Indeed the Ammonoosuc is full of stones that have come from the White Mountains all through the town of Littleton, and in the towns to the south. The late Prof. L. Agassiz wrote a paper¹ to prove the existence of a local glacier, coming down the north flank of Mount Lafayette, rising up over Bethle-

¹ Quoted in the State Geological Report.

hem, and some of it continuing over the col to the north of Mann's Hill, where some moraines may now be seen. We have, therefore, the best authority for accepting the view of the former presence of a local glacier down the valley of the Connecticut and its tributaries, which is illustrated by the most common of the striæ in Littleton.

This ice was thick enough to cover all of Littleton and the Gardner Mountain range, and hence exceeded 2000 feet in thickness. Its eastern border must have been a contour line of 2000 feet adjacent to Littleton, and 1800 feet as far south as Hanover. The same line of altitude would determine its limits on the Vermont side of the valley. Mount Ascutney, in Windsor, Vt., seems to have been an island or a measuring rod by which to determine the thickness of the ice at that latitude; and perhaps 2500 feet may represent the height of the glacier. The projecting top was thus what is called in Greenland a *Nunatak*.

The course of the Connecticut River along the northerly town line is about S. 70° W., being turned much to the west from its general direction. Being at right angles to the ice-movement in its earlier stages, the valley was sheltered from the direct impact of the ice, and seems to have furnished a lodging-place for the débris pushed along. It is said no ledge is exposed along the Fifteen-Miles Falls, except near the mouth of the Passumpsic; everywhere else the material is what geologists call *till*, or the *ground-moraine*, the ice-borne stones and sand. Could we dig down to the underlying ledges they would all be found smoothed and striated, as is the case universally elsewhere in the township. These facts indicate, first, a movement to smooth the rock, and, secondly, an accumulation of material.

Not till after the publication of the State Report was attention called to the existence of *terminal moraines* in connection with the ice-sheet. Such have been determined in the southern borders of New England and west of Hudson's River; and now it would appear that such deposits can be identified in and about Littleton. First, let any one travel to the northeast. For two miles northerly from Alder Brook the number of large boulders is incalculable. They are of gneiss and porphyritic granite of large size, too great to permit more than scanty clearings of the ground for agricultural purposes. They have not been transported far, because the ledges beneath are of much the same character. I hardly know of any other place in the State where there is such a tremendous array of stones. Yet, if one looks about him, at Quebec Junction in Whitefield and for a mile or two south, he will be confronted by a

similar array of boulders, perhaps the direct continuation of the moraine near Alder Brook.

East of the village of Littleton there is a large array of irregular hills of drift, into which excavations have been made in grading streets and in digging for the foundations of houses. These are in shape and mode of accumulation perfectly like the moraines of glaciers. Again, Mount Eustis is a mound of till. There is not a ledge anywhere about its higher part; and hence it is surely composed of transported material. In our search for the lenticular hills (or drumlins) in the south part of the State, it was proved satisfactorily that if a ledge was to be found anywhere about a hill it would be at the summit, because the moving of the ice would have pushed off everything where rock was present. Hence this mountain is a sample of a moraine. Just above it was stated that the ice pushed through the gap for the Waterford road in the direction S. 25° E., as indicated by the striæ. Now Eustis Mountain lies directly in the path of this movement. Can any one doubt, therefore, the origin of the mountain? The ice crowded the materials before it through the gap, and found the east side of the valley a barrier not easily surmounted. Hence the drift was piled up as much as 400 feet above its base as a terminal moraine.

Probably the next place for the lodgment of the ice-carried débris was at Partridge Pond, or above Young's Pond in Lyman. At both localities are rounded hills of till like the typical moraines. It is fifteen miles from Quebec Junction to Partridge Pond; and it seems quite proper to believe that this nearly continuous pile of débris and stones is to be considered as a part of the great terminal moraine of the ice-sheet. Its further limits may be determined by investigation.

Another point of interest in this connection is a speculation as to the origin of the open valley from Eustis Mountain across to Parker Brook. When the glacier was pushing rubbish across the valley, débris would accumulate at its terminus, but there would be much clear ice behind. So when the ice ceased to be urged forward, and melting ensued, there would be first a pond or river to the north of the moraine, and eventually only a valley. The streams washing out the finer parts of the till along the Ammonoosuc did not bring down enough to fill up this basin; so that now it remains as a witness to the truth of our conjecture respecting the former presence of ice.

MODIFIED DRIFT.—The water arising from the melting of the ice could not fail to be very abundant, and also to deposit much

sediment. The beautiful terraces, like those just to the west and south of the village, were formed in this way. Three streams — the Ammonoosuc and two tributaries — combined to form the extensive terrace upon which the cemetery is situated, and its highest part may be 75 feet above the Ammonoosuc. On the Connecticut the terraces are scarce, the most extensive being little deltas pushed into the main stream by the tributaries. At the extreme west corner of the town and opposite Lower Waterford, the modified drift is more plentiful. It consists of irregular hillocks of sand, barren of vegetation, and drifted by the wind in some places, rising to 200 feet above the Connecticut. It is the great slope of the river that seems to have prevented the accumulation of terraces through Littleton, since both above and below the Fifteen-Mile Falls the slopes are gradual, and the terraces widespread.

The theory of origin, as stated in the report, for the terraces is that they were formed by erosion from a flood plain. The enlarged river, swollen by the melting of the ice, brought along the rubbish derived from the ice itself, and filled up the whole valley, wherever the sediment was sufficiently abundant. It was the flood plain, much like the meadow or *intervale* of a high pitch of the river. As soon as the flood subsided the river cut its way down through the sand, leaving plains of greater or less extent. As the water did not subside immediately, there was opportunity for the formation of these plains at successive levels. There may be three of them near the village. From careful observations of the altitudes of these terraces all the way from Long Island Sound to Connecticut Lake, it has been found that there is a normal high terrace considerably constant in altitude, with a slope corresponding to the pitch of the stream. Were the river formerly a succession of lakes, the terraces or margins should be level, at least over the districts comparable to the expansions of the water.

ANCIENT EARTHQUAKE. — From one exposure of the glaciation of a ledge it is possible to see evidences of a powerful earthquake since the ice age. It is on a ledge just below a gateway near the summit of Kilburn's Crag. The glacial smoothings with *striæ* are abundant over several square yards of surface; but segments of the slate have been crowded up (or down) a quarter of an inch since the glaciation was effected. When made, the smoothing must have been continuous; now one part of the ledge, with the *striæ* upon it, is a quarter of an inch higher than what is adjacent, and the change is abrupt. These jogs in the ledge are small faults made by the same crowding from one side that has lifted up the mountains; or, to speak in accordance with what would

have been noticed at the time of disturbance, an observer must have felt a severe earthquake shock, probably more powerful than anything ever experienced in the whole history of the settlement of the town. This is the first disturbance of this nature described from any part of New England. Now that attention has been called to their existence, other illustrations will be discovered.

ROCKS OF LITTLETON.

SEDIMENTARY TERRANES.

QUATERNARY	{ Modified Drift.
	{ Glacial Till.
HELDERBERG	{ Blueberry Mountain Argillites.
	{ Coarse Conglomerates.
UPPER SILURIAN	{ Sandstones.
	{ Niagara Limestone and Slate.
SILURIAN	{ Swift Water Series.
	{ Coös Mica Schists and Quartzites.
LOWER SILURIAN OR CAMBRIAN	{ Hydro-mica Schist Group.

UNSTRATIFIED ROCKS.

BASIC ERUPTIVES	{ Diabase.
	{ Diorite.
METAMORPHIC	{ Diorite.
ERUPTIVES	{ Hornblendite.
ACIDIC ERUPTIVES	{ Granite.
	{ Protogene.
	{ Porphyritic Granite.

LIST OF MINERALS OCCURRING IN LITTLETON.

Gold.	Arsenopyrite.	Apatite.
Galenite.	Hematite.	Calcite.
Sphalerite.	Menaccanite.	Dolomite.
Pyrrhotite.	Magnetite.	Ankerite.
Pyrite.	Limonite.	Siderite.
Chalcopyrite.	Quartz.	Malachite.
Bornite.		

SILICATES.

Pyroxene (augite).	Biotite.	Tourmaline.
Hornblende.	Anorthite.	Fibrolite.
Garnet.	Labradorite.	Chlorite.
Epidote.	Orthoclase.	Sericite.
Muscovite	Oligoclase.	

APPENDIX

TO THE GEOLOGY OF LITTLETON.

By C. H. HITCHCOCK.

THE sketch of the Geology of Littleton (pages 3-29) was written in 1898, and printed in 1899, during the absence of the author from the country. The volume containing it is not yet ready for publication (October 5, 1904). Since 1899 I have been able to make further explorations, particularly in the towns of Lisbon and Lyman, and can add something to our knowledge of the geology of the district. Fortunately the map submitted in 1898 has not been engraved, so that it can be revised to accord with the latest interpretation of the facts. No change will be needed in what has been already printed; but I will indicate what improvements have been suggested by the additional studies in the town and neighborhood. A paper embodying the conclusions obtained was read before the Geological Society of America, December 30, 1903, and published in Vol. 15 of its Bulletin.

Our studies commenced with a careful examination of the fossils at Fitch Hill and elsewhere in Littleton. They were submitted to Mr. Charles Schuchert of the National Museum at Washington, who reported as follows: "The Littleton fauna is certainly Middle Upper Siluric. The species suggest the Niagara, and there is nothing so recent as the Lower Helderberg." It will be recalled that this limestone was called Helderberg in the State Report, and Niagara in later publications. Mr. Schuchert's statement refers the fossils to a horizon intermediate between the Niagara and the Lower Helderberg.

The next step taken was the effort to trace out the course of the limestone. There seem to be two lines of outcrop in Littleton, making a synclinal trough beneath the slates of Blueberry Mountain. Of these the western line may be followed through Lyman into Bath; the eastern cannot be traced continuously beyond Littleton, though it may connect with the fossiliferous limestones southwest from Mill Brook in Lisbon, and thence interruptedly to Smith Brook in the northeast angle of Bath.

The third band is quite conspicuously displayed at North Lisbon, and for two miles south near the Ammonoosuc River. The fourth calcareous band is known from about a mile east of Streeter Pond southwesterly nearly to Salmon Hole Brook in Lisbon. A fifth range is that from near Franconia Iron Works past Sugar Hill village and Bronson's lime quarry into Landaff.

The next point is to ascertain whether the adjacent overlying sandstone of the Blueberry range accompanies the other outcrops. A quartzite of analogous character occurs with the limestones of the fourth and fifth ranges, but is not well shown at North Lisbon, unless it be represented by a conglomerate. The typical Blueberry sections, however, show a coarse conglomerate upon both flanks characterized by pebbles of the size of the eggs of hens and geese, overlying the sandstones. The place of this coarse sediment towards Young's Pond in Lyman seems to be taken by the auriferous conglomerate of the State Report; so that it is clear that there is a mass of coarse and fine arenaceous sediments at approximately the same horizon above the limestone, and at the base of the slates of Blueberry Mountain.

This arenaceous zone is succeeded by the slates last named, which may well be termed for stratigraphical reasons Devonian-Silurian, in the absence of fossils.

Mention has been made of the novaculite upon Fitch Hill, it being produced by the effect of an igneous diorite upon slate. Analogous occurrences are spoken of as *contact-phenomena*. The first important study of these phenomena was undertaken by Dr. G. W. Hawes, one of the assistants upon the New Hampshire Geological Survey, after the publication of the Final Report, in the region of the White Mountain Notch. The argillitic schists of the Lyman group closely resemble the novaculite and similar rocks, now called *hornfels*. Our map shows an extensive area of these rocks from the country east of Partridge Lake across the township northeasterly into Dalton. They seem to have been produced by thermal influences acting upon earthy materials, — whether slates, sandstones, or conglomerates. Instead of a fiery mass converting a slate by its contact into hornfels, some source of heat has penetrated the ledges to a considerable depth and changed them *en masse* into a corresponding altered product. The Lyman schists, therefore, do not represent a stratigraphical terrane; it is a petrographical designation. At present it is not known what the original rocks were, but one of them must have been the arenaceous division of sands and conglomerates, and another an argillite. Early analyses of the argillite and Lyman

schist caused us to suggest the derivation of one from the other, because their chemical constitution was nearly identical.

The map presented herewith is based upon the historical map prepared by Ray T. Gile in 1895, very much reduced. An area in the north part of the town is left uncolored, because of the covering of the ledges by a thick mass of glacial till, which is very likely some variety of moraine. It is not convenient to separate the coarse conglomerates from the Blueberry Mountain argillite, nor to distinguish between the Swift Water schists and the Coös rocks. The various igneous rocks have a uniform color, but may easily be separated: for the porphyritic granite occupies the whole of the eastern corner; the Bethlehem protogene lies between Apthorp and South Littleton; the granitic gneiss is situated between the village of Littleton, Mann's Hill, and Black Mountain; and the later protogenes, diorites, and hornblendites are scattered in the smaller patches between Blueberry Mountain and Farr Hill.

Upon page 20 allusion is made to a peculiar igneous rock. Specimens have been submitted to the Smithsonian Institution for examination, and a report has been forwarded by R. Rathburn. It is basaltic, allied to the Limburgite or olivine diabase found in boulders at Thetford, Vt., and in place at Corinth, Vt. The Littleton specimen carries no blebs of olivine, but possesses instead large phenocrysts of biotite, while the Thetford rock abounds in large phenocrysts of augite and olivine. The points of resemblance between the two rocks strongly suggest a relationship if not an absolutely similar genesis. It now remains to discover the source of the boulders, which is quite as likely to be in Concord or Waterford as in Littleton.

A TRILOBITE (DALMANITES LUNATUS) FROM
LITTLETON, N. H., WITH NOTES ON OTHER
FOSSILS FROM THE SAME LOCALITY.

By AVERY E. LAMBERT.

THE extensive range of igneous and metamorphic rocks, which are necessarily devoid of any organic evidences, gave to those who first studied the geology of this State the conception that it must be considered Azoic.

That no remains of ancient forms of life could be found in New Hampshire, particularly in the region lying close to or within the White Mountain area, was emphasized by Louis Agassiz, whose influence was such in geology that in his day his word was practically looked upon as conclusive.

However, even before Agassiz had declared that it would be impossible to find evidences of the Paleozoic era in the New Hampshire rocks, corals, crinoidal stems, and brachiopods had been found in Littleton,—a fact which at a later time must have come to the knowledge of the great naturalist.

The discovery of corals and crinoidal stems was made by Dr. C. H. Hitchcock in the limestone formations of Littleton, September 28, 1870. That day a telegram was sent to the Dartmouth Scientific Society announcing the discovery in the following words: "No longer call New Hampshire Azoic. Silurian fossils found to-day." These fossils were sent to Mr. Billings, a Canadian geologist, for identification. Mr. Billings believed, from the evidence which they presented, that the general term "Helderberg" could be employed to indicate the geological horizon of this area.

Three years later a party consisting of Professor Hitchcock, Mr. J. H. Huntington, his assistant, and Mr. A. S. Batchellor, of Littleton, discovered the most important fossiliferous section of this area on the northern part of the range of hills popularly known as the Blueberry Mountains.

The limestone of this hill, commonly known as Fitch Hill, contains coral and crinoidal fragments quite similar to those found in the rocks in which the fossils were first discovered.

In 1885 Mr. T. Nelson Dale, working under the direction of R. Pumpelly, made a collection of the fossils of this region. In

his report¹ he calls the strata of this hill a "more or less argillaceous limestone" containing crinoidal fragments, *Favosites*, *Haly-sites*, *Pentamerus*, associated with slates, "some of which contain trilobites."

This trilobite was examined by Mr. C. D. Walcott, of the United States Geological Survey, who pronounced it identical with *Dalmanites limulurus*, a form belonging to the Niagara period of the Silurian age.

Practically nothing more was done in this locality until the fall of 1902, when Professor Hitchcock, accompanied by Mr. Leland Griggs and myself, again visited it and brought away enough material to afford convincing evidence that the place would repay a more thorough search.

In the early part of the summer of 1903 arrangements were made by means of which I was able to spend considerable time in the field, working here under the direction of Professor Hitchcock. The result of this investigation was the collection of coralline and crinoidal fragments, a number of fragments of the trilobite, together with an almost perfect specimen of the brachiopod which had already been reported as *Pentamerus nysius* and as *P. knighti*. These fossils are now in the collection at Dartmouth College.

The locality in which these fossils occur is easily accessible. The most direct way of approach is to ascend the hill, going south, from the house now owned by Mr. Frank Fitch. The fossiliferous rocks are distant from the road some four or five hundred feet.

In ascending the hill one crosses the following strata. First and lowest is the igneous rock which, breaking through horizontal sedimentary rocks, or, more probably, pushing up between and through the already tilted strata, has produced a great deal of the distortion which may be seen everywhere in the configuration of the hill.

Lying next to the igneous rock is a layer of coralline limestone, ranging from thirty to fifty feet in thickness; while over this, and gradually merging into it where the two come in contact, is the calciferous slate, from five to eight feet thick, in which the trilobites are found.

Above the trilobite-bearing slate is another limestone. Over this is a layer of coarse sandstone; while above the sandstone is another, though non-fossiliferous, layer of slate.²

¹ Proc. Canadian Institute, Toronto, vol. xxii. No. 146, p. 69.

² At the foot of the hill on the northeast side, in the road, near Parker Brook, is a mass of slate which I believe to be identical with this stratum, and in which I was

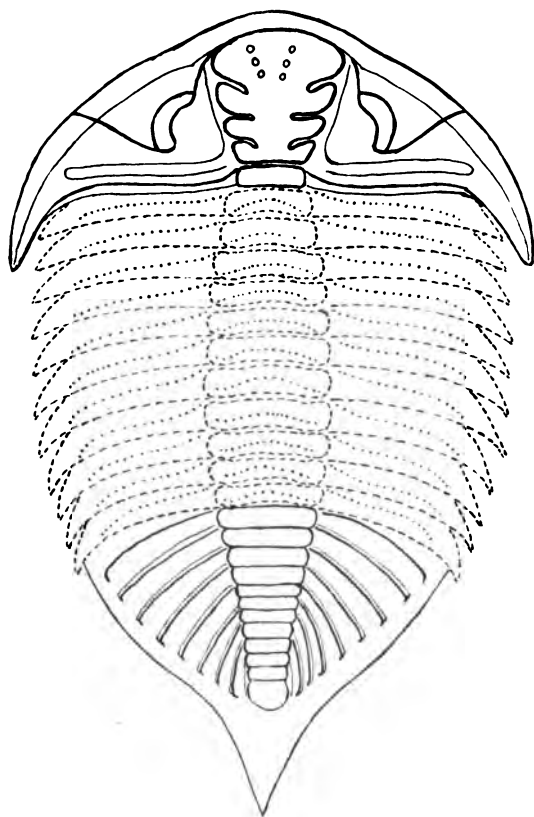


PLATE 1.

The rock in which the trilobite occurs has been distorted by pressure caused by the uptilting of the strata. This is indicated very clearly by the distorted condition in which many of the fossil fragments are found.

1. THE TRILOBITE. — The trilobites represent a group of the Crustacea — animals having a hard, shell-like outer covering — which is characteristic of the Paleozoic rocks. On account of the firmness of the texture of this outer shell, or exoskeleton, these animals are frequently found in the rocks, having the form excellently preserved.

The body is divided transversely into three parts, — the head, or cephalic shield; the thorax, or middle part; and the tail-piece, or pygidium.

There is a broad, median ridge on the cephalic shield, called the glabella. This is divided by three or four transverse furrows into a large frontal lobe, followed by three or four smaller transverse lobes.

The rest of the cephalic shield is made up of the fixed and free cheeks. The fixed cheeks are on either side of the glabella, and are continuous with it. The free cheeks are separated from the fixed cheeks by the facial suture, and lie toward the margin. The eyes are located on the free cheeks which, being movable, gave to the animal an increased range of vision.

The thorax was composed of several sections, or segments, so joined together that they could move freely upon one another. This articulated structure of the thorax enabled the animal to fold itself up, thus bringing the head and the tail together underneath. Not infrequently the fossil remains of trilobites are found in this position.

The pygidium was also segmented, but here the segments were fused together, the different parts being, in consequence, incapable of separate movement.

From the glabella on the cephalic shield to the posterior part of the pygidium there extended down the middle line of the body a sharply defined ridge, which is called the axis. The parts on either side of the axis are called the pleura. The body is thus given a threefold, or tri-lobed appearance, from which the animal derives its name.

A few specimens of the cephalic shields of the Littleton trilobite fortunate enough to find a crinoidal stem. Professor Hitchcock also assures me that he has found fossils in the slate, near an abandoned quarry on the west side of this range, the rock of which belongs to this stratum likewise. If the identification of these two masses with the upper strata is correct, then that layer cannot be said to be non-fossiliferous.

have been recovered ; but, owing to the loosely constructed character of the thorax, and to changes which have taken place in the rock in which the fossils are embedded, none of the thoracic segments have been preserved.

After visiting the locality in the fall of 1902, I made a careful examination of the specimens which I obtained there, comparing them with those already in the Dartmouth collections, and came to the conclusion that the Littleton trilobite did not approach near enough to *Dalmanites limulurus* in certain characters of the cephalic shield and pygidium to justify its identification with that species.

In the meantime specimens were sent to Mr. Charles Schuchert, of the National Museum, for examination. Mr. Schuchert concluded that the form could not be that of *Dalmanites limulurus*, but is between *Dalmanites limulurus* and *Dalmanites pleuropteryx*.

Since my conclusion seems to be the correct one, that this form does not approach near enough to *Dalmanites limulurus* to be identical with that species, I have taken the liberty to suggest, on account of the markedly lunate character of the head, that the Littleton fossil be known by the name of *DALMANITES LUNATUS*.

The following is a description of this form.

Dalmanites lunatus LAMBERT.

The cephalic shield strongly lunate. The glabella is divided by transverse furrows into an oval frontal portion, about twice as broad as long, followed by three transverse ridges the first of which is considerably broader than the remaining two. The occipital ring is not greatly thicker than the transverse ridges of the glabella. The glabella gradually becomes narrower, proceeding from the frontal lobe backward, and is devoid of marginal crenulations (Schuchert).

The fixed cheeks are separated from the glabella by a deep, narrow facial furrow, which runs longitudinally by the side of the glabella to a point just behind the third lobe, where it turns abruptly outward, ending near the base of the genal spine. All three of the transverse furrows of the glabella communicate more or less freely with the facial furrow.

The facial suture passes backward behind the eye from a point just in front of the glabella, then turning outward joins the margin at a place nearly in line with the middle of the eye.

The large and conspicuous compound eye is situated on the inner margin of the movable cheeks.

The border of the cephalic shield is broadened and forms the



Fig. 1.



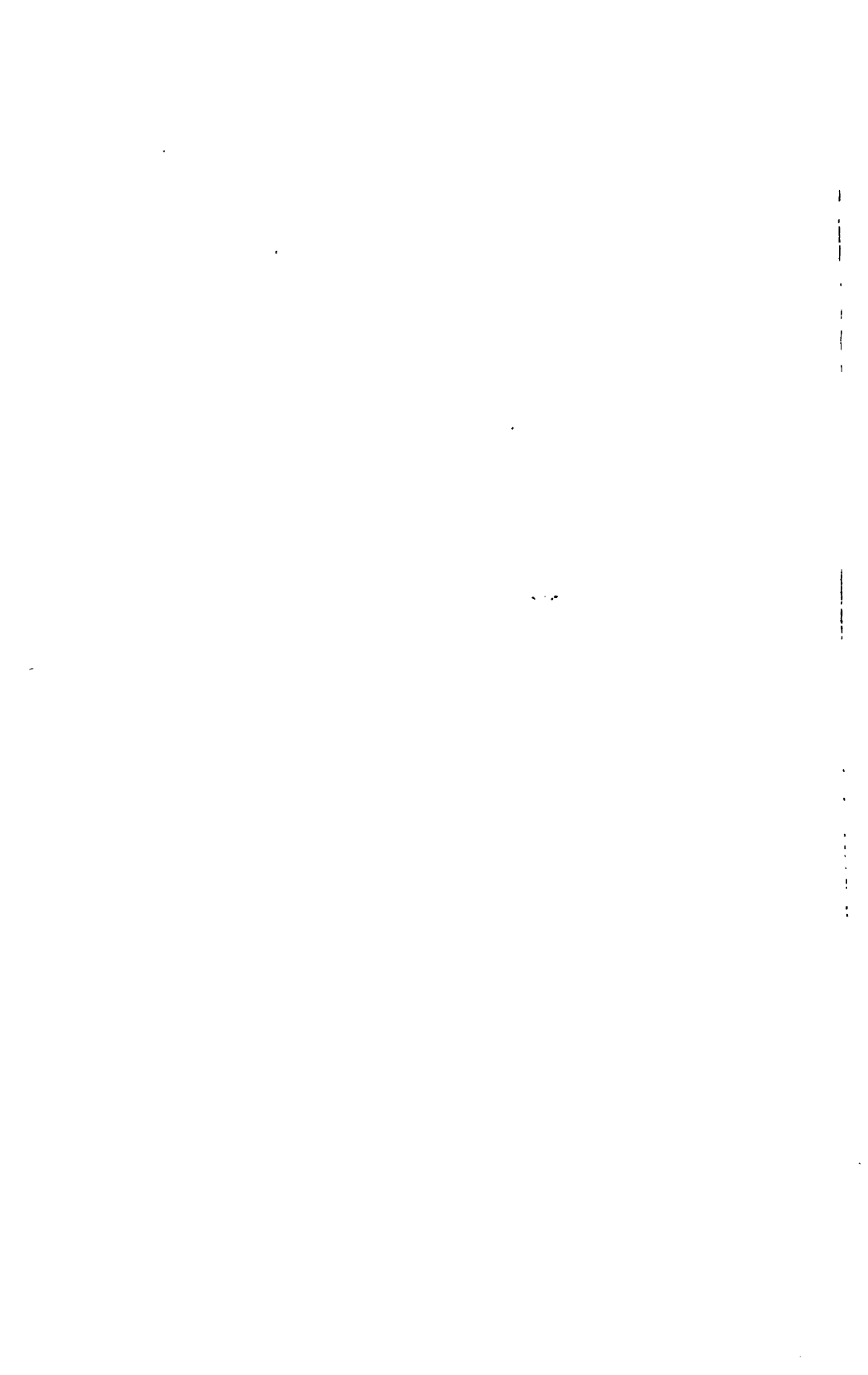
Fig. 3.



Fig. 2.

TRILOBITE FOSSILS FOUND ON FITCH HILL.

PLATE 2.



marginal limb. At the anterior edge the shield is produced into a slight, broadly curved projection. The posterior angles are produced into genal spines of only medium length.

The parts of the thorax have invariably been missing in the specimens which have been found. We may, however, assume that there were eleven segments, which number is fairly constant for this genus.

The pygidium is triangular in form. Its axial ridge is composed of thirteen segments. This ridge is considerably broader at the anterior part than at the posterior, which is about half the width of the anterior. The pleura of the pygidium are made up of eight segments whose lateral edges are lost in a broad, thick, marginal band which terminates behind in a short, sharp, wedge-shaped pygidial spine.

These characters point conclusively to the fact that we have in this trilobite a form which, as Mr. Schuchert has indicated, is between *Dalmanites limulurus* and *Dalmanites pleuropteryx*, and is, in all probability, considerably nearer to the latter than to the former.

2. OTHER FOSSILS FOUND IN THE LITTLETON LOCALITY. — A considerable variety of fossil forms have been found in the limestone which underlies the trilobite-bearing slate. Among these are tube and chain corals (*Favosites* and *Halysites*), fragments of crinoidal stems, and brachiopods.

The most conspicuous among these is a brachiopod — some nearly perfect specimens of which have been obtained — which was reported by Billings as *Pentamerus knighti*, but which Whitfield regarded (also Walcott) as *Pentamerus nysius*. Schuchert, however, concluded that this form belongs nearer to *Conchidium knighti* (*Pentamerus knighti*) than to *C. nysius*.

The shell bears but little resemblance to *C. nysius*, and while it approaches *C. knighti* in the bi-convex character of the dorsal valve, and in the closeness of the plications, it is much nearer in form to *C. galeatus* than it is to either of the above-mentioned forms. The differences are in the character of the plications and of the marginal fold, the edges of the shell not being folded into so conspicuous a furrow.

The following is a list of the fossils which have been reported from this locality: *Halysites catenulata*, *Favosites favosa*, *Zaphrentis*, *Favosites basaltica*, *Favosites gothlandica*, *Rhynchonella*, *Astrocerium venustum*, *Spirifer*, *Pleurotomaria*, *Strophodonta*, *Stromatopora*, *Syringopora*, *Favosites* — a ramose species, probably identical with *niagarensis*, *Dalmanites lunatus* (sp. nov.), *Conchidium* — near *galeatus*, and a crinoid stem.

3. THE GEOLOGICAL HORIZON OF THE LITTLETON LOCALITY. — Mr. Billings, after examining the fossils which were found in this locality in the years 1870 and 1873, asserted that the general term "Helderberg" should be used in determining the geological horizon of this area. The first observers of the paleontology of the region were impressed with the similarity which existed between the fossils found in the Littleton limestone and those found in like strata at Lake Memphremagog on the north, and Bernardstown, Mass., on the south, formations which are ascribed to the Helderberg period.

The conclusions of Mr. Billings, however, were not sustained by Mr. Walcott, who placed the strata in the Niagara, an earlier period of the Silurian age. His determination of the species did not agree with that of Mr. Billings, who made the most conspicuous brachiopod to be *Conchidium* (*Pentamerus*) *knighti*, whereas Mr. Walcott, following Mr. Whitfield, described it as *P.* (*Conchidium*) *nysius*.

Mr. Schuchert fails to follow either Mr. Billings or Mr. Walcott in regard to the identity of the species, making the brachiopod a *Conchidium* of the *knighti* type, though near, in some respects, as he says, to *galeatus*. He agrees with Mr. Walcott that the strata should be regarded as Niagaran.

But when we bear in mind that the trilobite comes much nearer to *Dalmanites pleuropteryx*, a form belonging to the lower Helderberg, than it does to *Dalmanites limulurus*, the Niagaran form, and that the brachiopod cannot be the Niagaran *Conchidium nysius*, but that it approaches more closely to *Conchidium galeatus*, a species characteristic of the lower Helderberg, we are justified in regarding these strata as representing a time somewhat later than the Niagara period. This supposition is strengthened by the presence of a *Rhynchonella*, presumably *Wilsonia*, though the identity is somewhat doubtful.

However, in such corals as *Halysites catenulata* and *Favosites favosa* we have the most direct evidence of the presence here, when these formations were in the process of making, of the life of the Niagara period. Certain of the corals are not determinable, and must be, in consequence, left out of consideration.

Where, then, are we to place this most interesting area? It would seem that the presence of characteristic Niagara forms, mingling with types that approach so closely to certain forms which are to be found only in the lower Helderberg, makes but one answer possible; and that is that these strata indicate a period in which the life of the Niagara was passing over into that of a later period.



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